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# EXPERIENCE FROM TRANSPORT OF LARGE OBJECTS IN SWEDEN FROM AN AUTHORITY'S POINT OF VIEW

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## ABSTRACT

Large contaminated or activated objects from replacement of components in nuclear power plants or from decommissioning have sometimes to be transported unpackaged due to their dimensions or masses. The objects have surface contamination on inner parts and/or are activated. The objects can sometimes be classified as SCO-I or SCO-II, but it is not always possible to verify that classification, due to inaccessible parts or that activation of the material can not be excluded. Examples of such objects are steam generators, reactor tank lids and turbine parts. A few such objects have been shipped from the nuclear power plants to an industrial installation specialized in decontamination, cutting, melting and conditioning of the radioactive waste or directly to a final storage for low and intermediate level waste in Sweden.

The Swedish nuclear power plants as well as the industrial site and the final storage for radioactive waste are all located close to the sea with harbours of their own. That usually makes sea transport with a dedicated ship the preferred mode of transport.

The experience from the shipments is good with in most cases insignificant doses to the transport personnel and without any serious mishaps.

The paper will give some examples of shipments of unpackaged large objects and describe the evaluation made by the Swedish competent authority before issuing approval for the shipments under special arrangement and the experience gained.

## INTRODUCTION

In Sweden electricity has been produced by means of nuclear power since the early 1970s. At present there are 10 nuclear power plants in operation (7 BWR and 3 PWR). Two BWRs have been taken out of operation for political reasons and are under safe storage with all fuel removed from the site. During the more than 30 years of operation of nuclear power plants in Sweden components have been replaced and the degraded components have been taken care of as radioactive waste. Metal parts have in some cases been recycled. There is also one nuclear installation in Sweden, Studsvik Nuclear AB, specialized in decontamination, segmenting, recycling metals as well as treatment and conditioning of radioactive waste.

All the Swedish nuclear power plants as well as the Studsvik site and the final storage for low and medium level waste are located close to the sea with own harbors. Most shipments to and from the Swedish nuclear facilities therefore take place by a dedicated sea transport system with an INF 3 ship – M/S Sigyn. This transport system has also been used for the shipments of large contaminated objects from the nuclear power plants to Studsvik Nuclear AB for decontamination, segmenting and recycling of metals. The components often have to be shipped unpackaged due to their dimensions and weight. The Swedish competent authority has after evaluation issued approval for shipment under special arrangement for these shipments on a case-by-case basis.

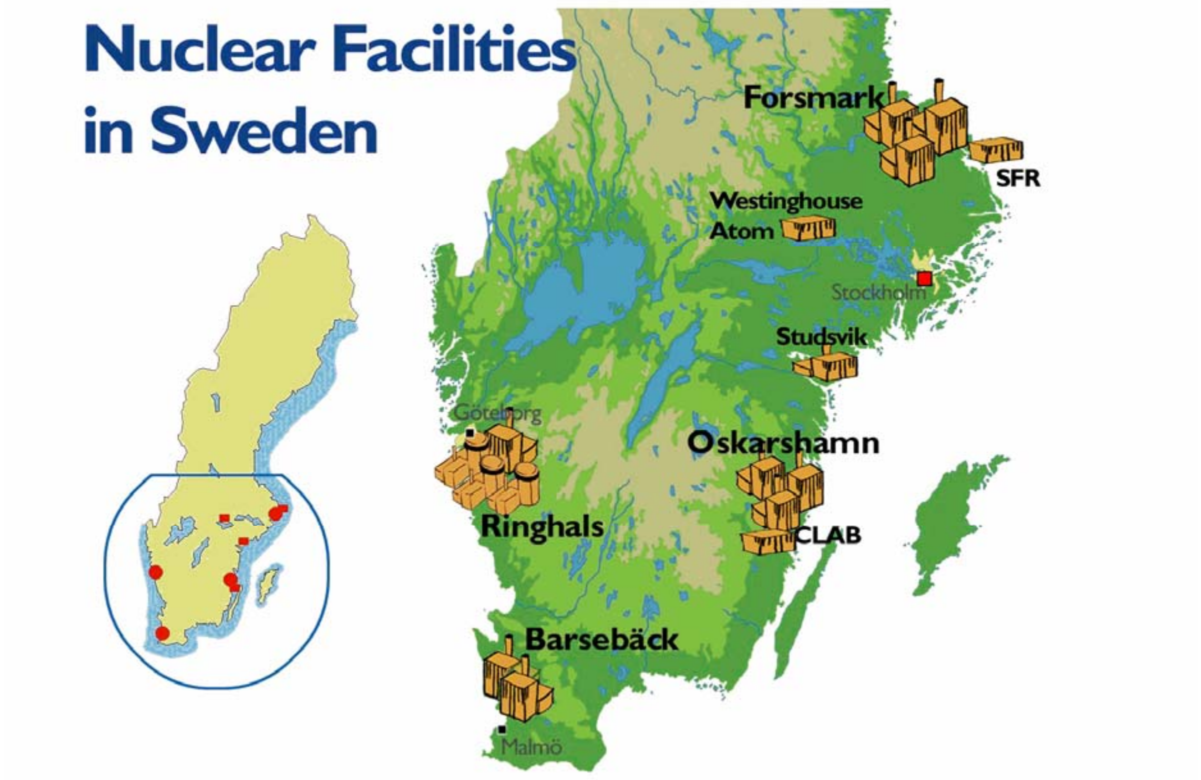


**Figure 1. Nuclear facilities in Sweden.**

## EXAMPLE OF SHIPMENTS

Three shipments of totally six steam generators, two shipments of reactor vessel lids, and several shipments of other components (e.g. parts from turbines, heat exchangers and intermediate heaters) have successfully been performed in Sweden without any serious mishaps and without significant exposure of the staff involved.

The components are often large and massive, measuring up to 4.5 m in diameter and 19 m in length. The mass has been up to 310 metric ton, excluding transport frame.

**Figure 2. Steam generator leaving Ringhals NPP, Sweden**

**Figure 3. Loading of a steam generator on the INF 3 ship M/S Sigyn**

## CLASSIFICATION OF THE RADIOACTIVE MATERIAL

The large components have surface contamination on their internal surfaces; in some cases also activation products are present. Steam generators and most other components contain only surface contamination, but due to non-uniform deposition on non-assessable areas there are often difficult, or even impossible, to verify that the object meets the definition of SCO-I or SCO-II for every 300 $cm^2$ as required by the Transport Regulations [1], even though the average surface contamination levels may usually be shown through calculation, reasoning arguments and measurements of samples to meet the limits.

When activation products also are present the classification is still more difficult. The surface contamination is usually dominating and the radioactive material from activation is not distributed throughout the object or essentially uniformly distributed. It is therefore not possible to meet the definition of LSA-II or LSA-III in the Transport Regulations [1].

In case the radioactive material meets the definition of SCO-II, an Industrial Package of Type 2 (IP-2) is required, but no IP-2 has been available for the largest components if they are not segmented before transport.

In the case of steam generators efforts have instead been made to show through calculations that the outer shell of the steam generator itself fulfils the requirements for an IP-2. The Transport Regulations [1] requires that the complete component shall be subject to the free drop test and the stacking test. The acceptance criteria for this test is

a) no loss or dispersal of the radioactive contents; and

b) not more than 20% increase in the maximum radiation level at any external surface of the package.

Calculations and engineering argumentation has not been able to demonstrate compliance with these requirements when being dropped in the direction that will cause maximum damage, only when the object is oriented in the transport position in a way that the weakest parts are protected.

**Figure 4. Unloading of a steam generator from M/S Sigyn.**

## EXPERIENCE FROM AN AUTHORITY'S POINT OF VIEW

The shipments described above have been transported under special arrangement after approval issued by the Swedish Radiation Protection Authority (SSI) on a case-by-case basis. The experience of SSI from evaluation of the applications is summarized below.

- Dimensions and weights require that the largest components are segmented into smaller pieces to find a packaging for the material. In Sweden there is a nuclear facility which is specialized in decontamination, segmenting, recycling of metal and treatment and conditioning of the radioactive waste. That installation has special equipment and trained personnel for that kind of work. An argument from the industry has been that the total collective dose to workers will be lower when the large component is transported in one piece instead of segmented at the reactor site, and is therefore an advantage from radiological point of view and in agreement with the ALARA principle.

- The objects can mostly be classified as SCO-II after calculations and measurements of samples when averaged over the whole component. It has not been possible to demonstrate that the definition of SCO-II is met over every 300 $cm^2$ of the inassessable internal parts of the large objects, due to non-uniform contamination.
- In the case of reactor vessel lids both surface contamination and activation products are present. It has not been possible to meet the definition of neither LSA-material nor SCO of the Transport Regulations [1]. The object is "something between" LSA-material and SCO.
- The total activity has been determined using a combination of measurements of samples, calculation and reasoning and the multiple of $A_2$ was calculated. The total activity has been determined to be more than $A_2$ but less than 5 $A_2$ for one steam generator.
- No liquid content is allowed.
- If the component itself is considered as the package, it must be demonstrated that it meets the stacking and free drop tests. Stacking can usually be shown to be impossible due to the shape of the component, or can be administratively prohibited. The drop test requirements can often be met in the transport position but not in the direction which causes the greatest damages.
- The radiation level at the surface of the component is often below or slightly more than 2 mSv/h, sometimes with extra shielding over openings. The radiation level at a distance of 1 m from the surface of the component is however often more than 0.1 mSv/h. In the case of reactor vessel lids the radiation levels are significantly higher, which require shielding.
- Studies of exposure of workers during transport of unpackaged large contaminated objects have shown that loading, lashing and unloading are the work operations which cause the main part of the whole body dose.

For shipments under special arrangement the Transport regulations [1] require that *the overall level of safety in transport shall be at least equivalent to that which would be provided if all the applicable requirements had been met*. The level of safety has to be demonstrated through means alternative to the other provisions. Such compensatory measures have included:

- Exclusive use shipment conditions.
- Shipments with the Swedish sea transport system for spent fuel and radioactive waste using an INF 3 ship.
- Trained personnel and health physics officers shall supervise the shipment from the radiological point of view. Members of the public are never allowed to come close to the shipment.
- All openings such as nozzles, blow-down lines, level-taps, man-ways etc are covered in a way that prevents loss of shielding or dispersal of material under normal conditions of transport.
- All accessible surfaces must meet the contamination limits, preferably by decontamination at the nuclear power plant. Additionally shrink-wrap coverings and tarpaulins have been used.
- If the component itself is considered as the package, it must be demonstrated that the drop test requirements are met in the transport position. The stacking test has not been considered relevant for the largest components.

- The radiation protection program has to be reviewed and sometimes revised to take the special features of the shipment into account.
- The emergency plan has to be reviewed and sometimes additionally measures added.
- The whole body dose to workers during handling and shipment should be measured and documented.

## CONCLUSIONS

Shipments of large contaminated or activated objects from replacements of components or dismantling of nuclear power plants, which cannot without great problems be segmented at the reactor site, are foreseen to become more frequent in the near future. Up till now the possibility of shipment under special arrangement has been applied on a case-by-case basis when all other provisions of the Transport Regulations [1] have not been possible or impracticable to meet.

Most shipments have been domestic but international shipments have taken place with approval from more than one competent authority.

International recommendations or guidelines for transport of large components would be of great value to advice the consignors about the requirements and help the competent authorities in their judgments concerning if *the overall level of safety in transport is at least equivalent to that which would be provided if all the applicable requirements had been met* as required by the Transport Regulations. Our experience is that this is a difficult issue and includes judgments which are difficult to quantify. To prepare and include recommendations and guidelines into the Transport Regulations [1] and the Advisory Material [2] so that transport of large contaminated or activated objects can be performed safely and with similar requirements in all countries would therefore be of great value for both consignors and competent authorities.

## REFERENCES


1. International Atomic Energy Agency, Regulations for the Safe Transport of Radioactive Material. 2005 Edition. IAEA Safety Standards Series No.TS-R-1. Vienna (2005).
2. International Atomic Energy Agency, Advisory Material for the IAEA Regulations for the Safe Transport of Radioactive Material. IAEA Safety Standards Series No. TS-G-1.1. Vienna (2002).